(54)   **Solder, method for processing surface of printed wiring board, and method for mounting electronic part**

(57)   A solder consists essentially of 1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, and the remaining of Sn and inevitable impurities.

FIG. 5
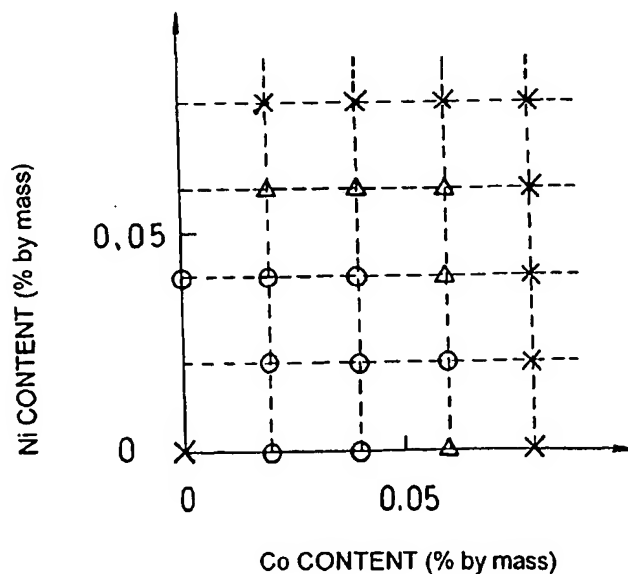
Description

[0001] The present invention relates to a Sn-Ag-Cu based solder, a method for processing a surface of a printed wiring board and a method for mounting an electronic part, in particular, to a solder, a method for processing a surface
5 of a printed wiring board and a method for mounting an electronic part, wherein the prevention of copper consuming is achieved at the time of soldering.

[0002] Conventionally an alloy of 63% of Sn and 37% of Pb by mass is utilized as a solder for coating a copper circuit on a printed wiring board and for the connection between a footprint or through holes in a printed wiring board and leads of parts to be mounted. Recently, however, environmental pollution due to lead that has eluted from discarded
10 electronic equipment has become a problem and solder that does not include Pb has been under intense development in the manufacturing of electronic parts.

[0003] As for lead-free solder that does not include Pb, a Sn-Cu based alloy, a Sn-Ag-Cu based alloy and a Sn-Zn based alloy are representative and alloys gained by adding Bi, In and/or Ge to these alloys have also been under examination.

15 [0004] As for the Sn-Cu based alloy. however, even an alloy of 99.2% of Sn and 0.8% of Cu by mass, which is of the eutectic composition. has a comparatively high melting point of 227°C and, therefore, there is a shortcoming wherein in the case that the composition is changed for the purpose of preventing the below described copper consuming, the melting point becomes higher so that the printed wiring board and electronic parts to be mounted cannot withstand high temperature at the time of soldering. The heat-resistant temperature of printed wiring boards in general use is
20 approximately 260°C.

[0005] As for the Sn-Zn based alloy. the solder melting point of 91% of Sn and 9% of Zn by mass, which is of the eutectic composition, is 199°C. which is close to the melting point, 183°C, of the alloy of 63% of Sn and 37% of Pb by mass, which is of eutectic composition Accordingly, this is an alloy that is favorable from the viewpoint of the melting point. However, since Zn is an active element, there is a shortcoming in that the solder is significantly oxidized so that
25 it is difficult to achieve a good soldering condition.

[0006] As for the Sn-Ag-Cu based alloy. the three element eutectic alloy of 95.8% of Sn, 3.5% of Ag and 0.8% of Cu by mass has a melting point of 217°C. which is higher than the melting point of the alloy of 63% of Sn and 37% of Pb by mass and the Sn-Zn based alloy and is still low enough for use as solder from the viewpoint of the heat resistance of printed wiring board and the like. In addition, even in a case where the processing temperature for coating a copper
30 circuit on a printed wiring board and for the connection between a footprint or through holes in a printed wiring board and leads of parts to be mounted is assumed to be 250°C, an excellent soldered condition can be gained, of which the mechanical characteristics are also excellent, and, therefore, the Sn-Ag-Cu based alloy is the most suitable for practical application from among the above described lead-free solders.

[0007] Sn-Ag-Cu based alloys are disclosed in, for example, Japanese Unexamined Patent Publication No. Hei
35 2-34295, Japanese Unexamined Patent Publication No. Hei 2-179388, Japanese Unexamined Patent Publication No. Hei 4-333391, Japanese Unexamined Patent Publication No. Hei 6-269983 and Japanese Unexamined Patent Publication No. Hei 11-77366. The solder disclosed in Japanese Unexamined Patent Publication No. Hei 2-34295 is for the purpose of providing a lead-free solder while the solder disclosed in Japanese Unexamined Patent Publication No. Hei 2-179388 is for the purpose of improving corrosion resistance and electrical and thermal conductivity. In addition,
40 the solder disclosed in Japanese Unexamined Patent Publication No. Hei 4-333391 is for the purpose of increasing creep characteristics, the solder described in Japanese Unexamined Patent Publication No. Hei 6-269983 is for the purpose of increasing wettability on the Ni based base material and the solder described in Japanese Unexamined Patent Publication No. Hei 11-77366 is for the purpose of increasing strength against thermal fatigue strength and joint characteristics.

45 [0008] In a case where a Sn-Ag-Cu based alloy is utilized, however, there is a problem wherein when the alloy is coated on a copper circuit of a printed wiring board by means of a hot air leveling method, the copper plating layer of the printed wiring board is consumed so as to be thinner and in the worst case wiring may be cut. In addition, in a case where parts are soldered through flow soldering, the copper plating layer of the printed wiring board is consumed and becomes thinner so as to cause soldering defects.

50 [0009] Therefore, a solder gained by adding 1% to 4% of Cu by mass to a Sn-Sb-Bi-In based alloy has been proposed (Japanese Unexamined Patent Publication No. Hei 11-77368). In addition, a solder gained by adding 1% to 3% of Cu by mass to a Sn-Zn-Ni based alloy, which is a Sn-Zn based alloy, has also been proposed (Japanese Unexamined Patent Publication No. Hei 9-94688).

[0010] Both of the solders disclosed in these gazettes are designed to prevent copper consuming by adding Cu. The
55 melting point of the former. however, is too high because the solidus temperature is 208°C while the liquidus temperature is 342°C. Since the latter is a Sn-Zn based alloy, there is a problem concerning oxidation as described above.

[0011] Moreover, in Japanese Unexamined Patent Publication No. Hei 11-216591 data gained by actually carrying out the measurement of the alloys of 96% of Sn, 3.5% of Ag and 0.5% of Co by mass as well as 98.8% of Sn, 0.7%

can be gained regardless of whether or not an electronic part is mounted thereon.

Fig. 1 is a phase diagram of an Sn-2%Ag-Cu-0.04%Co alloy with the Cu content indicated along the horizontal axis;

Fig. 2 is a diagram of Sn-Ag-Cu-Co(-Ni) showing the relationship between the Co content and the Cu content when the Ag content is fixed at 2% by mass, wherein Fig. 2A is in the case of Ni free, while Fig. 2B is in the case of containing 0.04% of Ni by mass;

Fig. 3 is a diagram of Sn-Ag-Cu-Co(-Ni) showing the relationship between the Co content and the Ag content when the Cu content is fixed at 0.8% by mass, wherein Fig. 3A is in the case of Ni free, while Fig. 3B is in the case of containing 0.04% of Ni by mass;

Fig. 4A is a graph of Sn-2%Ag-0.8%Cu-0.04%Co-Ni showing the relationship between the Ni content and the liquidus temperature while Fig. 4B is a graph of Sn-2%Ag-0.8%Cu-0.04%Co-Ni showing the relationship between the Ni content and the melting rate of copper;

Fig. 5 is a graph of Sn-Ag-Cu-Co-Ni showing the evaluation result of the relationship between the Co content and the Ni content when the Ag content is fixed at 2% by mass and the Cu content is fixed at 0.8% by mass;

Fig. 6A is a graph of Sn-3.5%Ag-0.8%Cu-0.06%Co-Fe showing the relationship between the Fe content and the liquidus temperature while Fig. 6B is a graph of Sn-3.5%Ag-0.8%Cu-0.06%Co-Fe showing the relationship between the Fe content and the melting rate of copper;

Fig. 7 is a graph of Sn-Ag-Cu-Co-Fe showing the evaluation result of the relationship between the Co content and the Fe content when the Ag content is fixed at 3.5% by mass and the Cu content is fixed at 0.8% by mass;

Fig. 8 is a graph of Sn-Ag-Cu-Co-Ni-Fe showing the relationship between the Ni content and the Fe content when the Ag content is fixed at 3.5% by mass, the Cu content is fixed at 0.8% by mass and the Co content is varied; and

Fig. 9A is a graph of Sn-Ag-Cu-Co showing the relationship between the Co content and the liquidus temperature in a solder of Sn, 3.5% of Ag by mass and 0.8% of Cu by mass while Fig. 9B is a graph of Sn-Ag-Cu-Co showing the relationship between the Co content and the melting rate of copper in the solder of Sn, 3.5% of Ag by mass and 0.8% of Cu by mass.

[0027] As a result of repeated and diligent experimental research by the inventors of the present application in order to solve the above described problems, it has been found that copper consuming can be prevented by adding a proper amount of Co while controlling the increase in the liquidus temperature, for example, by controlling the liquidus temperature at 230°C or below, which is preferable in regard to the heat-resistant temperature of the printed wiring board and, in addition, this prevention effect can be increased by adding a proper amount of Ni and/or Fe. The melting rate of copper in a case wherein the inventors of the present application added a variety of elements to Sn is shown in the following Table 1. Table 1 shows that the higher the melting rate of copper is, the easier copper consuming progresses.

[Table 1]

Composition (% by mass)									Melting rate of copper (μm/sec)
Sn	Ag	Cu	Bi	In	Zn	Fe	Ni	Co	
100	0	0	0	0	0	0	0	0	0.61
98.8	1.2	0	0	0	0	0	0	0	0.41
96.5	3.5	0	0	0	0	0	0	0	0.27
99.6	0	0.4	0	0	0	0	0	0	0.43
99.2	0	0.8	0	0	0	0	0	0	0.29
98.8	0	1.2	0	0	0	0	0	0	0.17
98	0	0	2	0	0	0	0	0	0.50
96	0	0	4	0	0	0	0	0	0.42
92	0	0	8	0	0	0	0	0	0.32
98	0	0	0	2	0	0	0	0	0.47
96	0	0	0	4	0	0	0	0	0.38
92	0	0	0	8	0	0	0	0	0.29
99	0	0	0	0	1	0	0	0	0.20

[Table 1]   (continued)

Composition (% by mass)									Melting rate of copper (μm/sec)
Sn	Ag	Cu	Bi	In	Zn	Fe	Ni	Co	
98	0	0	0	0	2	0	0	0	0.06
96	0	0	0	0	4	0	0	0	0.02
91	0	0	0	0	9	0	0	0	0.01
99.98	0	0	0	0	0	0.02	0	0	0.52
99.96	0	0	0	0	0	0.04	0	0	0.46
99.94	0	0	0	0	0	0.06	0	0	0.41
99.98	0	0	0	0	0	0	0.02	0	0.45
99.96	0	0	0	0	0	0	0.04	0	0.35
99.94	0	0	0	0	0	0	0.06	0	0.26
99.98	0	0	0	0	0	0	0	0.02	0.4
99.96	0	0	0	0	0	0	0	0.04	0.3
99.94	0	0	0	0	0	0	0	0.06	0.25

[0028]   As shown in the above Table 1, in a case where a minute amount of Co, Ni or Fe is added, the melting rate of copper is significantly reduced in comparison with cases where other elements are added. In particular, the reduction of the melting rate of copper is significant at the time when Co, from among these three types of elements, is added. In general, as the amount of other elements added to an alloy that has a eutectic composition increases, the liquidus temperature increases and in the case where the amount of the addition is minute, the increase in the liquidus temperature can be limited to the minimum. Accordingly, it is considered that by adding a minute amount of Co, Ni and/or Fe, copper consuming can be prevented while controlling the increase in the liquidus temperature.

[0029]   In the following, the chemical components contained in solders according to the present invention and the reason why the solders are limited to such compositions are described.

Ag: 1.0% to 4.0% by mass

[0030]   Ag is an element that has the effect of increasing the wettability of solder. That is to say, by adding Ag, the time that the solder is to be wet can be shortened. The results of measuring the wettability of solders of Sn-Ag-Cu based alloys by means of a wetting balance method prescribed in Clause 8.3.1.2 of JIS Z 3197 are shown in the following Table 2. In this test, a phosphorous-deoxidized copper plate, of which the thickness is 0.3 mm, the width is 5 mm, and the length is 50 mm was utilized as a test piece after being heated for 20 minutes at 130°C so as to be oxidized. In addition, a solution gained by adding and dissolving 0.39 ± 0.01g of diethylamine hydrochloride into a solution gained by dissolving 25g of rosin as flux into isopropyl alcohol was utilized. The temperature of the solder bath was 250°C, the rate of immersion into the solder bath was 16 mm/sec, the depth of immersion was 2 mm and the time of immersion was 10 sec.

[Table 2]

Composition (% by mass)			Solidus temperature (°C)	Liquidus temperature (°C)	Melting rate of copper copper (μm/sec)	Wetted time (sec)
Sn	Ag	Cu				
100	0	0	232	232	0.61	5.42
99.6	0	0.4	227	230	0.43	2.37
99.2	0	0.8	227	227	0.29	2.2
98.8	0	1.2	227	244	0.17	2.22
98.4	0	1.6	227	259	0.04	2.96

[Table 2] (continued)

Composition (% by mass)			Solidus temperature (°C)	Liquidus temperature (°C)	Melting rate of copper copper (μm/sec)	Wetted time (sec)
Sn	Ag	Cu				
98.8	1.2	0	221	228	0.41	1.4
98.4	1.2	0.4	217	226	0.30	1.55
98	1.2	0.8	217	224	0.19	1.49
97.6	1.2	1.2	217	237	0.13	1.73
97.2	1.2	1.6	217	253	0.07	3.48
96.5	3.5	0	221	221	0.27	1.43
96.1	3.5	0.4	217	219	0.18	1.24
95.7	3.5	0.8	217	217	0.13	1.16
95.3	3.5	1.2	217	226	0.08	1.41
94.9	3.5	1.6	217	242	0.04	2.97

[0031] As shown in Table 2. the amount of time that a solder, of Sn-Cu based alloys to which Ag is not added, was to be wet exceeded 2 sec in all cases while the amount of time that a solder, of a Sn-1.2%Ag-Cu based alloy or of a Sn-3.5%Ag-Cu based alloy to which Ag is added, was to be wet was within 2 sec in most cases.

[0032] Here, in the case where the content of Ag in the solder is less than 1.0% by mass, the above described effect of a shortened wetted time cannot be gained. On the other hand, when the Ag content exceeds 4.0% by mass, the liquidus temperature becomes high so that there is a risk that a defect will occur to a printed wiring board and to electronic parts at the time of soldering. Accordingly, the content of Ag in the solder should be in a range of 1.0% to 4.0% by mass.

Cu: 0.2% to 1.3% by mass

[0033] Cu is an element that has the effect of preventing copper consuming of a copper circuit on a printed wiring board. The characteristics of JIS H63A solder that is a Sn-Pb eutectic solder and to which Cu is added are shown in the following Table 3.

[Table 3]

Cu content (% by mass)	Solidus temperature (°C)	Liquidus temperature (°C)	Melting rate of copper (μm/sec)
0	183	183	0.10
0.1	183	183	0.08
0.2	183	198	0.07
0.3	183	218	0.05
0.4	183	236	0.04
0.5	183	250	0.02

[0034] As shown in Table 3, as the Cu content increases, the melting rate of copper is lowered so as to prevent copper consuming. On the other hand, the liquidus temperature increases.

[0035] In the case where the content of Cu in the solder is less than 0.2% by mass, the above-described effect of preventing copper consuming is insufficient. On the other hand, when the Cu content exceeds 1.3% by mass, the liquidus temperature becomes high so that there is a risk that a defect will occur to the printed wiring board and to the electronic parts at the time of soldering. Fig. 1 is a phase diagram of an alloy of Sn-2%Ag-Cu-0.04%Co, with the Cu content indicated along the horizontal axis. In Fig. 1, the solid line shows the liquidus temperature and the double dotted chain line shows the solidus temperature. For example, in the case of an alloy of Sn-2%Ag-Cu-0.04%Co, when

the Cu content exceeds 1.3% by mass, the liquidus temperature exceeds 240°C as shown in Fig. 1. Accordingly, the content of Cu in the solder is in a range of 0.2% to 1.3% by mass.

[0036]   The relationships between Ag and Cu contents and the liquidus temperature (°C) and the melting rate of copper (μm/sec) in an Sn-Ag-Cu based solder are shown in the following Tables 4 and 5, respectively. In these solders the remaining components are all Sn.

[Table 4]

Liquidus temperature (°C)		Cu content (% by mass)						
		0	0.2	0.4	0.8	1	1.2	1.6
Ag content (% by mass)	0	232	230	229	227	235	244	259
	0.5	231	230	228	226	233	241	257
	1	229	228	227	225	231	238	254
	2	226	225	224	222	227	233	249
	3	222	222	221	219	224	228	244
	3.5	221	220	219	217	222	226	242
	4	228	227	226	224	229	233	249
	5	240	239	238	236	241	245	261

[Table 5]

Melting rate of copper (μm/sec)		Cu content (% by mass)						
		0	0.2	0.4	0.8	1	1.2	1.6
Ag content (% by mass)	0	0.610	0.520	0.430	0.290	0.230	0.170	0.100
	0.5	0.510	0.440	0.370	0.240	0.195	0.150	0.085
	1	0.435	0.380	0.320	0.200	0.170	0.135	0.075
	2	0.340	0.290	0.240	0.160	0.140	0.110	0.060
	3	0.290	0.240	0.190	0.140	0.120	0.090	0.045
	3.5	0.270	0.220	0.180	0.130	0.110	0.080	0.040
	4	0.260	0.210	0.170	0.120	0.100	0.080	0.035
	5	0.250	0.200	0.160	0.110	0.090	0.070	0.030

Co: 0.02% to 0.06% by mass

[0037]   Co is an element that has the effect of preventing copper consuming through the addition of a minute amount thereof as described above. Here, in the case where the content of Co in the solder is less than 0.02% by mass, the effect of preventing copper consuming cannot be gained. On the other hand, when the Co content exceeds 0.06% by mass, the liquidus temperature becomes high so that there is a risk that a defect may be caused to the printed wiring board and to the electronic parts at the time of soldering. In addition, since the viscosity becomes high, the unconformities as shown in the following are caused. First, in the case where the copper circuit on the printed wiring board is coated with solder by means of a hot air leveling method, a defect occurs wherein the thickness of the solder coating becomes uneven. In addition, in some cases a critical defect occurs wherein no solder coating is established or wherein a solder bridge between the adjoining circuits is formed. Secondly, the solder jet flow in the flowing solder becomes unstable so as to lower the yield of soldering and dispersion occurs in the amount of solder of the portion connected through solder to an electronic part so that a critical unconformities occurs wherein the reliability of connections is lowered. Accordingly, the content of Co in the solder should be in a range of 0.02% to 0.06% by mass. In addition, in the case where the Co content is 0.02% to 0.04% by mass, it is more favorable because the increase in the liquidus temperature is extremely small.

Ni: 0.02% to 0.06% by mass

[0038] Ni is an element that has the effect of preventing copper consuming through the addition of a minute amount thereof in the same manner as Co as described above. Here, in the case where the content of Ni in the solder is less than 0.02% by mass, the effect of preventing copper consuming through the addition of Ni cannot be gained. On the other hand, when the Ni content exceeds 0.06% by mass, the liquidus temperature becomes high so that there is a risk that a defect may be caused to the printed wiring board and to the electronic parts at the time of soldering. Accordingly, the content of Ni in the solder is in a range of 0.02% to 0.06% by mass.

Fe: 0.02% to 0.06% by mass

[0039] Fe is an element that has the effect of preventing copper consuming through the addition of a minute amount thereof in the same manner as Ni as described above. Here, in the case where the content of Fe in the solder is less than 0.02% by weight, the effect of preventing copper consuming cannot be gained. On the other hand, when the Fe content exceeds 0.06% by weight, the liquidus temperature becomes high so that there is a risk that a defect may be caused to the printed wiring board and to the electronic parts at the time of soldering. In addition, since the viscosity becomes high, the wettability of the solder is lowered. Accordingly, the content of Fe in the solder should be in a range of 0.02% to 0.06% by weight.

[0040] In the case where a circuit formed on the surface of a printed wiring board is coated with solder that has such a composition, a printed wiring board of which the copper consuming is extremely small can be gained. In addition, in the case where an electronic part is soldered to a circuit formed on the surface of a printed wiring board with a solder that has such a composition, the reliability of the mounting can be enhanced.

[0041] As described above, it is preferable for the liquidus temperature (melting point) of the solder to be 240°C or less, and it is more preferable for the liquidus temperature of the solder to be 230°C or less. Furthermore, it is preferable for the melting rate of copper to be 0.17 μm/sec, or less, for practical use.

[0042] In the following, the embodiments of the present invention are described concretely in relation to comparison examples that are out of the scope of the claims.

[0043] First, solders that have compositions as in the described Tables 6 through 14 below were prepared. Here, the remaining portions in the compositions shown in Figs. 6 through 14 are all Sn and inevitable impurities.

[Table 6]

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
1	2	0.2	0	0
2	2	0.2	0.02	0
3	2	0.2	0.04	0
4	2	0.2	0.06	0
5	2	0.2	0.08	0
6	2	0.2	0.1	0
7	2	0.2	0.12	0
8	2	0.2	0	0.04
9	2	0.2	0.02	0.04
10	2	0.2	0.04	0.04
11	2	0.2	0.06	0.04
12	2	0.2	0.08	0.04
13	2	0.2	0.1	0.04
14	2	0.2	0.12	0.04
15	2	0.4	0	0
16	2	0.4	0.02	0

[Table 6] (continued)

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
17	2	0.4	0.04	0
18	2	0.4	0.06	0
19	2	0.4	0.08	0
20	2	0.4	0.1	0
21	2	0.4	0.12	0
22	2	0.4	0	0.04
23	2	0.4	0.02	0.04
24	2	0.4	0.04	0.04
25	2	0.4	0.06	0.04
26	2	0.4	0.08	0.04
27	2	0.4	0.1	0.04
28	2	0.4	0.12	0.04

[Table 7]

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
29	2	0.8	0	0
30	2	0.8	0.02	0
31	2	0.8	0.04	0
32	2	0.8	0.06	0
33	2	0.8	0.08	0
34	2	0.8	0.1	0
35	2	0.8	0.12	0
36	2	0.8	0	0.04
37	2	0.8	0.02	0.04
38	2	0.8	0.04	0.04
39	2	0.8	0.06	0.04
40	2	0.8	0.08	0.04
41	2	0.8	0.1	0.04
42	2	0.8	0.12	0.04
43	2	0.8	0.04	0.02
44	2	0.8	0.04	0.06
45	2	0.8	0.04	0.08
46	2	0.8	0.04	0.1
47	2	0.8	0.04	0.12

[Table 8]

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
48	2	1.2	0	0
49	2	1.2	0.02	0
50	2	1.2	0.04	0
51	2	1.2	0.06	0
52	2	1.2	0.08	0
53	2	1.2	0.1	0
54	2	1.2	0.12	0
55	2	1.2	0	0.04
56	2	1.2	0.02	0.04
57	2	1.2	0.04	0.04
58	2	1.2	0.06	0.04
59	2	1.2	0.08	0.04
60	2	1.2	0.1	0.04
61	2	1.2	0.12	0.04
62	2	1.6	0	0
63	2	1.6	0.02	0
64	2	1.6	0.04	0
65	2	1.6	0.06	0
66	2	1.6	0.08	0
67	2	1.6	0.1	0
68	2	1.6	0.12	0
69	2	1.6	0	0.04
70	2	1.6	0.02	0.04
71	2	1.6	0.04	0.04
72	2	1.6	0.06	0.04
73	2	1.6	0.08	0.04
74	2	1.6	0.1	0.04
75	2	1.6	0.12	0.04

[Table 9]

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
76	0.5	0.8	0	0
77	0.5	0.8	0.02	0
78	0.5	0.8	0.04	0
79	0.5	0.8	0.06	0

[Table 8]

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
48	2	1.2	0	0
49	2	1.2	0.02	0
50	2	1.2	0.04	0
51	2	1.2	0.06	0
52	2	1.2	0.08	0
53	2	1.2	0.1	0
54	2	1.2	0.12	0
55	2	1.2	0	0.04
56	2	1.2	0.02	0.04
57	2	1.2	0.04	0.04
58	2	1.2	0.06	0.04
59	2	1.2	0.08	0.04
60	2	1.2	0.1	0.04
61	2	1.2	0.12	0.04
62	2	1.6	0	0
63	2	1.6	0.02	0
64	2	1.6	0.04	0
65	2	1.6	0.06	0
66	2	1.6	0.08	0
67	2	1.6	0.1	0
68	2	1.6	0.12	0
69	2	1.6	0	0.04
70	2	1.6	0.02	0.04
71	2	1.6	0.04	0.04
72	2	1.6	0.06	0.04
73	2	1.6	0.08	0.04
74	2	1.6	0.1	0.04
75	2	1.6	0.12	0.04

[Table 9]

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
76	0.5	0.8	0	0
77	0.5	0.8	0.02	0
78	0.5	0.8	0.04	0
79	0.5	0.8	0.06	0

[Table 9] (continued)

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
80	0.5	0.8	0.08	0
81	0.5	0.8	0.1	0
82	0.5	0.8	0.12	0
83	0.5	0.8	0	0.04
84	0.5	0.8	0.02	0.04
85	0.5	0.8	0.04	0.04
86	0.5	0.8	0.06	0.04
87	0.5	0.8	0.08	0.04
88	0.5	0.8	0.1	0.04
89	0.5	0.8	0.12	0.04
90	1	0.8	0	0
91	1	0.8	0.02	0
92	1	0.8	0.04	0
93	1	0.8	0.06	0
94	1	0.8	0.08	0
95	1	0.8	0.1	0
96	1	0.8	0.12	0
97	1	0.8	0	0.04
98	1	0.8	0.02	0.04
99	1	0.8	0.04	0.04
100	1	0.8	0.06	0.04
101	1	0.8	0.08	0.04
102	1	0.8	0.1	0.04
103	1	0.8	0.12	0.04

[Table 10]

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
104	3.5	0.8	0	0
105	3.5	0.8	0.02	0
106	3.5	0.8	0.04	0
107	3.5	0.8	0.06	0
108	3.5	0.8	0.08	0
109	3.5	0.8	0.1	0
110	3.5	0.8	0.12	0
111	3.5	0.8	0	0.04
112	3.5	0.8	0.02	0.04

[Table 10] (continued)

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
113	3.5	0.8	0.04	0.04
114	3.5	0.8	0.06	0.04
115	3.5	0.8	0.08	0.04
116	3.5	0.8	0.1	0.04
117	3.5	0.8	0.12	0.04
118	4	0.8	0	0
119	4	0.8	0.02	0
120	4	0.8	0.04	0
121	4	0.8	0.06	0
122	4	0.8	0.08	0
123	4	0.8	0.1	0
124	4	0.8	0.12	0
125	4	0.8	0	0.04
126	4	0.8	0.02	0.04
127	4	0.8	0.04	0.04
128	4	0.8	0.06	0.04
129	4	0.8	0.08	0.04
130	4	0.8	0.1	0.04
131	4	0.8	0.12	0.04

[Table 11]

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
132	5	0.8	0	0
133	5	0.8	0.02	0
134	5	0.8	0.04	0
135	5	0.8	0.06	0
136	5	0.8	0.08	0
137	5	0.8	0.1	0
138	5	0.8	0.12	0
139	5	0.8	0	0.04
140	5	0.8	0.02	0.04
141	5	0.8	0.04	0.04
142	5	0.8	0.06	0.04
143	5	0.8	0.08	0.04
144	5	0.8	0.1	0.04
145	5	0.8	0.12	0.04

[Table 12]

No.	Composition (% by mass)			
	Ag	Cu	Co	Ni
146	2	0.1	0	0
147	2	0.1	0.02	0
148	2	0.1	0.06	0
149	2	0.1	0.06	0
150	2	0.1	0	0.04
151	2	0.1	0.02	0.04
152	2	0.1	0.06	0.04
153	2	0.1	0.08	0.04
154	2	0.8	0.02	0.02
155	2	0.8	0.02	0.06
156	2	0.8	0.02	0.08
157	2	0.8	0.06	0.02
158	2	0.8	0.06	0.06
159	2	0.8	0.06	0.08
160	2	0.8	0.06	0.02
161	2	0.8	0.06	0.06
162	2	0.8	0.06	0.08

[Table 13]

No.	Composition (% by mass)			
	Ag	Cu	Co	Fe
163	3.5	0.8	0.02	0.02
164	3.5	0.8	0.02	0.06
165	3.5	0.8	0.02	0.08
166	3.5	0.8	0.06	0.02
167	3.5	0.8	0.06	0.06
168	3.5	0.8	0.06	0.08
169	3.5	0.8	0.08	0.02
170	3.5	0.8	0.08	0.06
171	3.5	0.8	0.08	0.08

[Table 14]

No.	Composition (% by mass)				
	Ag	Cu	Co	Ni	Fe
172	3.5	0.8	0.02	0.02	0.02
173	3.5	0.8	0.02	0.02	0.06

[Table 14] (continued)

No.	Composition (% by mass)				
	Ag	Cu	Co	Ni	Fe
174	3.5	0.8	0.02	0.02	0.08
175	3.5	0.8	0.02	0.06	0.02
176	3.5	0.8	0.02	0.06	0.06
177	3.5	0.8	0.02	0.06	0.08
178	3.5	0.8	0.02	0.08	0.02
179	3.5	0.8	0.02	0.08	0.06
180	3.5	0.8	0.02	0.08	0.08
181	3.5	0.8	0.06	0.02	0.02
182	3.5	0.8	0.06	0.02	0.06
183	3.5	0.8	0.06	0.02	0.08
184	3.5	0.8	0.06	0.06	0.02
185	3.5	0.8	0.06	0.06	0.06
186	3.5	0.8	0.06	0.06	0.08
187	3.5	0.8	0.06	0.08	0.02
188	3.5	0.8	0.06	0.08	0.06
189	3.5	0.8	0.06	0.08	0.08
190	3.5	0.8	0.08	0.02	0.02
191	3.5	0.8	0.08	0.02	0.06
192	3.5	0.8	0.08	0.02	0.08
193	3.5	0.8	0.08	0.06	0.02
194	3.5	0.8	0.08	0.06	0.06
195	3.5	0.8	0.08	0.06	0.08
196	3.5	0.8	0.08	0.08	0.02
197	3.5	0.8	0.08	0.08	0.06
198	3.5	0.8	0.08	0.08	0.08

[0044] Then, the melting rate of copper, the melting temperature, the viscosity and the solder spreadability were measured with respect to each of these solders.

[0045] In measuring the melting rate of copper, an isopropyl alcohol solution containing 20% of rosin by mass was coated, as a flux, on a copper wire of which the diameter was 0.5 mm and, after that, the copper wire was immersed in a solder bath for a fixed period of time and, then, the amount of decrease in the radius of the copper wire was measured.

[0046] In measuring the melting temperature, the solidus temperature was measured by means of a differential thermal analysis method. In addition, a melted solder was put into a test cup so that the viscosity thereof was measured by a Viscotester-VT-04 (made by Rion Co., Ltd.) while the temperature of the solder was gradually cooled down from about 310°C so as to determine the temperature where the viscosity suddenly increased, which was the liquidus temperature. At the time of measurement of this melting temperature, the viscosity was also measured.

[0047] The measurement of the solder spreadability was based on the "8.3.1.1 spread test" described in the soldering flux test method of JIS Z 3197. Concretely, 0.3g of solder and flux were placed on an oxidized copper plate that was heated for 30 sec at 250°C so as to spread the solder. After that, the solder was solidified by cooling and the height thereof was measured so as to calculate the solder spreadability.

[0048] The results of the above are shown in the following Tables 15 through 23. In the Tables 15 through 23, O, Δ

and × are attached in accordance with the following standards. A liquidus temperature that is 230°C or less is denoted as O, a liquidus temperature that exceeds 230°C and is 240°C or less is denoted as Δ, and a liquidus temperature that exceeds 240°C is denoted as ×. A melting rate of copper less than 0.17 (μm/sec) is denoted as O, a melting rate of copper that is 0.17 (μm/sec) or more and is less than 0.20 (μm/sec) is denoted as Δ and a melting rate of copper that is 0.20 (μm/sec) or more is denoted as ×. A viscosity that is 2.5 (cP) or less is denoted as O and a viscosity that exceeds 2.5 (cP) is denoted as ×. A solder spreadability that is 75 (%) or more is denoted as O and a solder spreadability that is less than 75 (%) is denoted as ×. Then, a synthetic evaluation (total) that includes × in any item is denoted as ×, a synthetic evaluation that includes Δ in any item from among synthetic evaluations that are not denoted as × is denoted as Δ and the remaining synthetic evaluations, that is to say the synthetic evaluations with O for every item, are denoted as C.

[Table 15]

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP)		Spreadability (%)		Total
1	217	224	O	0.28	×	1.9	O	77	O	×
2	217	224	O	0.18	Δ	1.9	O	77	O	Δ
3	217	224	O	0.12	O	1.9	O	77	O	O
4	217	235	Δ	0.1	O	1.9	O	77	O	Δ
5	217	250	×	0.08	O	2	O	77	O	×
6	217	263	×	0.06	O	2.5	O	76	O	×
7	217	275	×	0.04	O	3	×	76	O	×
8	217	224	O	0.25	×	1.9	O	77	O	×
9	217	224	O	0.16	O	1.9	O	77	O	O
10	217	224	O	0.1	O	1.9	O	77	O	O
11	217	237	Δ	0.08	O	1.9	O	77	O	Δ
12	217	252	×	0.06	O	2.1	O	77	O	×
13	217	265	×	0.05	O	2.7	×	76	O	×
14	217	278	×	0.03	O	3.2	×	76	O	×
15	217	223	O	0.25	×	1.9	O	77	O	×
16	217	223	O	0.15	O	1.9	O	77	O	O
17	217	223	O	0.1	O	1.9	O	77	O	O
18	217	234	Δ	0.08	O	1.9	O	77	O	Δ
19	217	249	×	0.06	O	2	O	77	O	×
20	217	264	×	0.05	O	2.4	O	76	O	×
21	217	276	×	0.03	O	2.9	×	76	O	×
22	217	223	O	0.22	×	1.9	O	77	O	×
23	217	223	O	0.13	O	1.9	O	77	O	O
24	217	223	O	0.09	O	1.9	O	77	O	O
25	217	235	Δ	0.07	O	1.9	O	77	O	Δ
26	217	250	×	0.05	O	2	O	77	O	×
27	217	265	×	0.03	O	2.5	O	76	O	×
28	217	278	×	0.02	O	3	×	76	O	×

[Table 16]

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP)		Spreadability (%)		Total
29	217	221	O	0.21	×	1.9	O	77	O	×
30	217	221	O	0.11	O	1.9	O	77	O	O
31	217	221	O	0.07	O	1.9	O	77	O	O
32	217	232	Δ	0.05	O	1.9	O	77	O	Δ
33	217	248	×	0.03	O	2	O	77	O	×
34	217	264	×	0.02	O	2.6	×	77	O	×
35	217	277	×	0.01	O	3.1	×	76	O	×
36	217	221	O	0.11	O	1.9	O	77	O	O
37	217	221	O	0.07	O	1.9	O	77	O	O
38	217	221	O	0.05	O	1.9	O	77	O	O
39	217	234	Δ	0.03	O	1.9	O	77	O	Δ
40	217	250	×	0.02	O	2	O	77	O	×
41	217	267	×	0.01	O	2.7	×	77	O	×
42	217	281	×	0	O	3.3	×	76	O	×
43	217	221	O	0.06	O	1.9	O	77	O	O
44	217	237	Δ	0.04	O	1.9	O	77	O	Δ
45	217	253	×	0.03	O	2.1	O	77	O	×
46	217	270	×	0.02	O	2.8	×	77	O	×
47	217	284	×	0.01	O	3.5	×	76	O	×

[Table 17]

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP)		Spreadability (%)		Total
48	217	234	Δ	0.16	O	1.9	O	77	O	Δ
49	217	234	Δ	0.09	O	1.9	O	77	O	Δ
50	217	234	Δ	0.05	O	1.9	O	77	O	Δ
51	217	236	Δ	0.04	O	1.9	O	77	O	Δ
52	217	252	×	0.03	O	2	O	77	O	×
53	217	266	×	0.02	O	2.7	×	77	O	×
54	217	279	×	0.01	O	3.2	×	76	O	×
55	217	234	Δ	0.1	O	1.9	O	77	O	Δ
56	217	234	Δ	0.06	O	1.9	O	77	O	Δ
57	217	234	Δ	0.04	O	1.9	O	77	O	Δ
58	217	237	Δ	0.03	O	1.9	O	77	O	Δ
59	217	254	×	0.02	O	2.1	O	77	O	×

[Table 17]   (continued)

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP)		Spreadability (%)		Total
60	217	270	×	0.01	O	2.8	×	77	O	×
61	217	283	×	0	O	3.4	×	76	O	×
62	217	248	×	0.1	O	1.9	O	77	O	×
63	217	248	×	0.07	O	1.9	O	77	O	×
64	217	248	×	0.04	O	1.9	O	77	O	×
65	217	250	×	0.03	O	1.9	O	77	O	×
66	217	254	×	0.02	O	2.1	O	77	O	×
67	217	266	×	0.01	O	2.7	×	76	O	×
68	217	280	×	0	O	3.8	×	75	O	×
69	217	248	×	0.08	O	1.9	O	77	O	×
70	217	248	×	0.05	O	1.9	O	77	O	×
71	217	248	×	0.03	O	1.9	O	77	O	×
72	217	251	×	0.02	O	2.1	O	77	O	×
73	217	256	×	0.01	O	2.3	O	77	O	×
74	217	268	×	0.01	O	2.9	×	76	O	×
75	217	283	×	0	O	3.9	×	75	O	×

[Table 18]

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP)		Spreadability (%)		Total Total
76	217	225	O	0.24	×	1.9	O	76	O	×
77	217	225	O	0.15	O	1.9	O	76	O	O
78	217	225	O	0.09	O	1.9	O	76	O	O
79	217	230	O	0.06	O	1.9	O	76	O	O
80	217	241	×	0.04	O	1.9	O	76	O	×
81	217	254	×	0.03	O	2.1	O	76	O	×
82	217	266	×	0.02	O	2.7	×	75	O	×
83	217	225	O	0.15	O	1.9	O	76	O	O
84	217	225	O	0.09	O	1.9	O	76	O	O
85	217	225	O	0.05	O	1.9	O	76	O	O
86	217	230	O	0.04	O	1.9	O	76	O	O
87	217	243	×	0.03	O	1.9	O	76	O	×
88	217	256	×	0.02	O	2.2	O	76	O	×
89	217	269	×	0.01	O	2.9	×	75	O	×
90	217	224	O	0.23	×	1.9	O	77	O	×
91	217	224	O	0.13	O	1.9	O	77	O	O

[Table 18]   (continued)

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP)		Spreadability (%)		Total Total
92	217	224	O	0.08	O	1.9	O	77	O	O
93	217	230	O	0.06	O	1.9	O	77	O	O
94	217	240	Δ	0.04	O	1.9	O	77	O	Δ
95	217	253	×	0.03	O	2.1	O	77	O	×
96	217	265	×	0.02	O	2.7	×	76	O	×
97	217	224	O	0.14	O	1.9	O	77	O	O
98	217	224	O	0.09	O	1.9	O	77	O	O
99	217	224	O	0.07	O	1.9	O	77	O	O
100	217	232	Δ	0.05	O	1.9	O	77	O	Δ
101	217	241	×	0.03	O	1.9	O	77	O	×
102	217	255	×	0.02	O	2.2	O	77	O	×
103	217	268	×	0.01	O	2.8	×	76	O	×

[Table 19]

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP) (cP)		Spreadability (%) (%)		Total Total
104	217	217	O	0.17	Δ	1.9	O	78	O	Δ
105	217	217	O	0.09	O	1.9	O	78	O	O
106	217	217	O	0.05	O	1.9	O	78	O	O
107	217	228	O	0.03	O	1.9	O	78	O	O
108	217	242	×	0.02	O	1.9	O	78	O	×
109	217	256	×	0.01	O	2.3	O	77	O	×
110	217	270	×	0	O	2.8	×	76	O	×
111	217	217	O	0.12	O	1.9	O	78	O	O
112	217	217	O	0.07	O	1.9	O	78	O	O
113	217	217	O	0.04	O	1.9	O	78	O	O
114	217	228	O	0.03	O	1.9	O	78	O	O
115	217	248	×	0.02	O	2	O	78	O	×
116	217	265	×	0.01	O	2.6	×	77	O	×
117	217	280	×	0	O	3	×	76	O	×
118	217	216	O	0.15	O	1.9	O	78	O	O
119	217	216	O	0.08	O	1.9	O	78	O	O
120	217	216	O	0.05	O	1.9	O	78	O	O
121	217	220	O	0.03	O	1.9	O	78	O	O
122	217	227	O	0.02	O	1.9	O	78	O	O
123	217	235	Δ	0.01	O	2	O	77	O	Δ

[Table 19] (continued)

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP) (cP)		Spreadability (%) (%)		Total Total
124	217	248	×	0	O	2.6	×	77	O	×
125	217	216	O	0.12	O	1.9	O	78	O	O
126	217	216	O	0.06	O	1.9	O	78	O	O
127	217	216	O	0.04	O	1.9	O	78	O	O
128	217	220	O	0.03	O	1.9	O	78	O	O
129	217	228	O	0.02	O	2	O	78	O	O
130	217	237	Δ	0.01	O	2.1	O	77	O	Δ
131	217	252	×	0	O	2.8	×	77	O	×

[Table 20]

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP)		Spreadability (%)		Total Total
132	217	236	Δ	0.11	O	2	O	77	O	Δ
133	217	236	Δ	0.06	O	2	O	77	O	Δ
134	217	236	Δ	0.04	O	2 ·	O	77	O	Δ
135	217	236	Δ	0.03	O	2	O	77	O	Δ
136	217	241	×	0.02	O	2	O	77	O	×
137	217	256	×	0.01	O	2.4	O	77	O	×
138	217	281	×	0	O	3.1	×	76	O	×
139	217	236	Δ	0.09	O	2	O	77	O	Δ
140	217	236	Δ	0.05	O	2	O	77	O	Δ
141	217	236	Δ	0.03	O	2	O	77	O	Δ
142	217	240	Δ	0.02	O	2	O	77	O	Δ
143	217	246	×	0.01	O	2	O	77	O	×
144	217	260	×	0	O	2.6	×	77	O	×
145	217	287	×	0	O	3.3	×	76	O	×

[Table 21]

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (μm/sec)		Viscosity (cP)		Spreadability (%)		Total Total
146	217	225	O	0.30	×	1.9	O	77	O	×
147	217	225	O	0.19	Δ	1.9	O	77	O	Δ
148	217	236	Δ	0.11	O	2.0	O	77	O	Δ
149	217	248	×	0.09	O	2.0	O	77	O	×
150	217	225	O	0.27	×	1.9	O	77	O	×

[Table 21]   (continued)

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (µm/sec)		Viscosity (cP)		Spreadability (%)		Total Total
151	217	225	O	0.17	O	1.9	O	77	O	O
152	217	238	Δ	0.09	O	2.0	O	77	O	Δ
153	217	256	×	0.07	O	2.2	O	77	O	×
154	217	221	O	0.09	O	1.9	O	77	O	O
155	217	232	Δ	0.05	O	1.9	O	77	O	Δ
156	217	250	×	0.04	O	2.1	O	77	O	×
157	217	221	O	0.04	O	1.9	O	77	O	O
158	217	236	Δ	0.03	O	2.0	O	77	O	Δ
159	217	254	×	0.02	O	2.2	O	77	O	×
160	217	246	×	0.03	O	2.1	O	77	O	×
161	217	254	×	0.02	O	2.2	O	77	O	×
162	217	266	×	0.01	O	2.4	O	76	O	×

[Table 22]

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (µm/sec)		Viscosity (cP) (cP)		Spreadability (%) (%)		Total Total
163	217	217	O	0.10	O	1.9	O	77	O	O
164	217	219	O	0.09	O	1.9	O	77	O	O
165	217	221	O	0.09	O	2.0	O	77	O	O
166	217	222	O	0.05	O	1.9	O	77	O	O
167	217	224	O	0.04	O	2.0	O	77	O	O
168	217	226	O	0.04	O	2.1	O	77	O	O
169	217	244	×	0.02	O	2.1	O	77	O	×
170	217	246	×	0.02	O	2.2	O	77	O	×
171	217	248	×	0.02	O	2.3	O	77	O	×

[Table 23]

No.	Solidus temperature (°C)	Liquidus temperature (°C)		Melting rate of copper (µm/sec)		Viscosity (cP)		Spreadability (%)		Total
172	217	217	O	0.07	O	1.9	O	77	O	O
173	217	219	O	0.06	O	2.1	O	77	O	O
174	217	221	O	0.06	O	2.3	O	77	O	O
175	217	230	O	0.04	O	2.0	O	77	O	O
176	217	232	Δ	0.04	O	2.3	O	77	O	Δ
177	217	234	Δ	0.03	O	2.5	O	77	O	Δ

[Table 23]   (continued)

No.	Solidus temperature (°C)	Liqu tempera		Melting rat (μm		Viscos		Spreada		Total
178	217	248	×	0.03	O	2.2	O	77	O	×
179	217	250	×	0.03	O	2.5	O	77	O	×
180	217	252	×	0.03	O	2.8	×	77	O	×
181	217	224	O	0.04	O	2.0	O	77	O	O
182	217	226	O	0.03	O	2.3	O	77	O	O
183	217	228	O	0.03	O	2.7	×	77	O	×
184	217	232	Δ	0.03	O	2.1	O	77	O	Δ
185	217	234	Δ	0.02	O	2.4	O	77	O	Δ
186	217	236	Δ	0.02	O	2.9	×	77	O	×
187	217	250	×	0.02	O	2.3	O	77	O	×
188	217	252	×	0.02	O	2.6	×	77	O	×
189	217	254	×	0.02	O	3.1	×	77	O	×
190	217	246	×	0.02	O	2.2	O	76	O	×
191	217	248	×	0.02	O	2.6	×	77	O	×
192	217	250	×	0.02	O	3.0	×	77	O	×
193	217	254	×	0.01	O	2.4	O	77	O	×
194	217	256	×	0.01	O	2.7	×	77	O	×
195	217	258	×	0.01	O	3.1	×	77	O	×
196	217	266	×	0.01	O	2.6	×	76	O	×
197	217	268	×	0.01	O	2.9	×	76	O	×
198	217	270	×	0.01	O	3.4	×	77	O	×

[0049]   The results of the above are shown in a graph. Here, O, Δ and × shown in the following graph indicates synthetic evaluations in the above described Tables 15 through 23.

[0050]   Figs. 2A and 2B are graphs showing the relationships between the Co content and the Cu content when the Ag content is fixed at 2% by mass. Fig. 2A is a graph showing the evaluation result of the case where Ni is not contained while Fig. 2B is a graph showing the evaluation result of the case that 0.04% of Ni by mass is contained. That is to say, Fig. 2A shows the evaluation results of Nos. 1 to 7, Nos. 15 to 21, Nos. 29 to 35, Nos. 48 to 54, Nos. 62 to 68 and Nos. 146 to 149 while Fig. 2B shows the evaluation results of Nos. 8 to 14, Nos. 22 to 28, Nos. 36 to 42, Nos. 55 to 61, Nos. 69 to 75 and Nos. 150 to 153.

[0051]   Figs. 3A and 3B are graphs showing the relationship between the Co content and the Ag content when the Cu content is fixed at 0.8% by mass. Fig. 3A is a graph showing the evaluation result of the case wherein Ni is not contained while Fig. 3B is a graph showing the evaluation result of the case wherein 0.04% of Ni by mass is contained. That is to say, Fig. 3A shows the evaluation results of Nos. 29 to 35, Nos. 76 to 82, Nos. 90 to 96, Nos. 104 to 110, Nos. 118 to 124 and Nos. 132 to 138 while Fig. 3B shows the evaluation results of Nos. 36 to 42, Nos. 83 to 89, Nos. 97 to 103, Nos. 111 to 117, Nos. 125 to 131 and Nos. 139 to 145.

[0052]   Figs. 4A and 4B are graphs showing the relationship between the Ni content and the liquidus temperature while Fig. 4B is a graph showing the relationship of the Ni content and the melting rate of copper. That is to say, Figs. 4A and 4B show the evaluation results of No. 31, No. 38 and Nos. 43 to 47 (evaluation results with respect to a solder of Sn-2% of Ag by mass-0.8% of Cu by mass-0.04% of Co by mass-Ni). Fig. 5 is a graph showing the evaluation result of relationships between the Co content and the Ni content when the Ag content is fixed at 2% by mass and the Cu content is fixed at 0.8% by mass. That is to say, Fig. 5 shows the evaluation results of Nos. 29 to 33, Nos. 36 to 40, Nos. 43 to 45 and Nos. 154 to 162.

[0053] Fig. 6A is a graph showing the relationship between the Fe content and the liquidus temperature while Fig. 6B is a graph showing the relationship between the Fe content and the melting rate of copper. That is to say, Figs. 6A and 6B show the evaluation results of No. 107 and Nos. 166 to 168 (evaluation results with respect to a solder of Sn-3.5% of Ag by mass-0.8% of Cu by mass-0.06% of Co by mass-Fe). Fig. 7 is a graph showing the evaluation results of relationships between the Co content and the Fe content when the Ag content is fixed at 3.5% by mass and the Cu content is fixed at 0.8% by mass. That is to say, Fig. 7 shows the evaluation results of Nos. 104 to 108 and Nos. 163 to 171.

[0054] Figs. 8A, 8B and 8C are graphs showing evaluation results of relationships between the Ni content and the Fe content when the Ag content is fixed at 3.5% by mass, the Cu content is fixed at 0.8% by mass and the Co content is varied. Fig. 8A is a graph showing the evaluation result when the Co content is 0.02% by mass, Fig. 8B is a graph showing the evaluation result when the Co content is 0.06% by mass and Fig. 8C is a graph showing the evaluation result when the Co content is 0.08% by mass. That is to say, Fig. 8A shows the evaluation results of No. 105, No. 112, Nos. 163 to 165 and Nos. 172 to 180, Fig. 8B shows the evaluation results of No. 107, No. 114, Nos. 166 to 168 and Nos. 181 to 189 and Fig. 8C shows the evaluation results of No. 108, No. 115, Nos. 169 to 171 and Nos. 190 to 198.

[0055] As shown in Figs. 2A and 2B, in the case where Co is in a range of 0.02% to 0.06% by mass, excellent results are gained even when the Ag content varies in a range of from 1.0% to 4.0% by mass, which is in the range of the present invention. Similarly, as shown in Figs. 3A and 3B, in the case where Co is in a range of 0.02% to 0.06% by mass, excellent results are gained even when the Cu content varies in a range of 0.2% to 1.3% by mass, which is in the range of the present invention.

[0056] In addition, as shown in Figs. 4 and Figs. 6, in the case where Ni or Fe is contained when the content thereof is 0.06% or less by mass, the liquidus temperature is of a degree wherein the electronic parts and the like are not affected at the time of soldering while in the case where the Ni content exceeds 0.08% by mass, the liquidus temperature exceeds 250°C so as to be in a range wherein damage is caused to the electronic parts and the like. In the case where Ni is contained, as shown in Figs. 4, the liquidus temperature does not increase at all or increases by an extremely small amount in comparison with a solder not containing Ni having the same content of Ag, Cu and Co, while the melting rate of copper further decreases. In the case where Fe is contained, as shown in Fig. 6, the liquidus temperature lowers further in comparison with the case where Fe is not contained, while the melting rate of copper is controlled to a low rate.

[0057] As shown in Fig. 5, Table 21 and the like, in the case where the Co content is in a range of 0.02% to 0.06% by mass and the Ni content is in a range of 0.02% to 0.06% by mass, good results are gained. In particular, in the case where the Co content is in a range of 0.02% to 0.04% by mass and the Ni content is in a range of 0.02% to 0.04% by mass, even better results are gained. Similarly, as shown in Fig. 7, Table 22 and the like, in the case where the Co content is in a range of 0.02% to 0.06% by mass and the Fe content is in a range of 0.02% to 0.06% by mass, good results are gained.

[0058] In addition, as shown in Figs. 8, in the case where Ni and Fe are contained in addition to Co, when the Co content, the Ni content and the Fe content are all in a range of 0.02% to 0.06% by mass, good results are gained.

[0059] The effects of adding Co to a solder of Sn-3.5% of Ag by mass-0.8% of Cu by mass, which is a conventional Sn-Ag-Cu based solder, are illustrated in graphs based on the above-described tables. Fig. 9A is a graph showing the relationship between the Co content and the liquidus temperature in the solder of Sn-3.5% of Ag by mass-0.8% of Cu by mass while Fig. 9B is a graph showing the relationship between the Co content and the melting rate of copper in the solder of Sn-3.5% of Ag by mass-0.8% of Cu by mass.

[0060] It can also be understood from Fig. 9A and Fig. 9B that in the case where the Co content is in the range of 0.02% to 0.06% by mass, copper consuming can be prevented by reducing the melting rate of copper while controlling the liquidus temperature within a range wherein the printed wiring board, the electronic parts to be mounted and the like are not negatively affected.

Claims

1. A solder consisting essentially of:

   1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, and the remaining of Sn and inevitable impurities.

2. A solder consisting essentially of:

   1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, 0.02% to 0.06% of Ni by mass, and the remaining of Sn and inevitable impurities.

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3. A solder consisting essentially of:

1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, 0.02% to 0.06% of Fe by mass. and the remaining of Sn and inevitable impurities.

4. A solder consisting essentially of:

1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, 0.02% to 0.06% of Ni by mass. 0.02% to 0.06% of Fe by mass, and the remaining of Sn and inevitable impurities.

5. The solder according to any one of claims 1 to 4, **characterized in that** the liquidus temperature is 240°C or less, and that the melting rate of copper is 0.17 μm/sec or less.

6. A method for processing a surface of a printed wiring board comprising the step of:

coating a circuit formed on a surface of a printed wiring board with a solder consisting essentially of 1.0% to 4.0% of Ag by mass. 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, and the remaining of Sn and inevitable impurities.

7. A method for processing a surface of a printed wiring board comprising the step of:

coating a circuit formed on a surface of a printed wiring board with a solder consisting essentially of 1.0% to 4.0% of Ag by mass. 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, 0.02% to 0.06% of Ni by mass, and the remaining of Sn and inevitable impurities.

8. A method for processing a surface of a printed wiring board comprising the step of:

coating a circuit formed on a surface of a printed wiring board with a solder consisting essentially of 1.0% to 4.0% of Ag by mass. 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, 0.02% to 0.06% of Fe by mass, and the remaining of Sn and inevitable impurities.

9. A method for processing a surface of a printed wiring board comprising the step of:

coating a circuit formed on a surface of a printed wiring board with a solder consisting essentially of 1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, 0.02% to 0.06% of Ni by mass, 0.02% to 0.06% of Fe by mass, and the remaining of Sn and inevitable impurities.

10. The method for processing a surface of a printed wiring board according to any one of claims 6 to 9, **characterized in that** the liquidus temperature of said solder is 240°C or less, and that the melting rate of copper is 0.17 μm/sec or less.

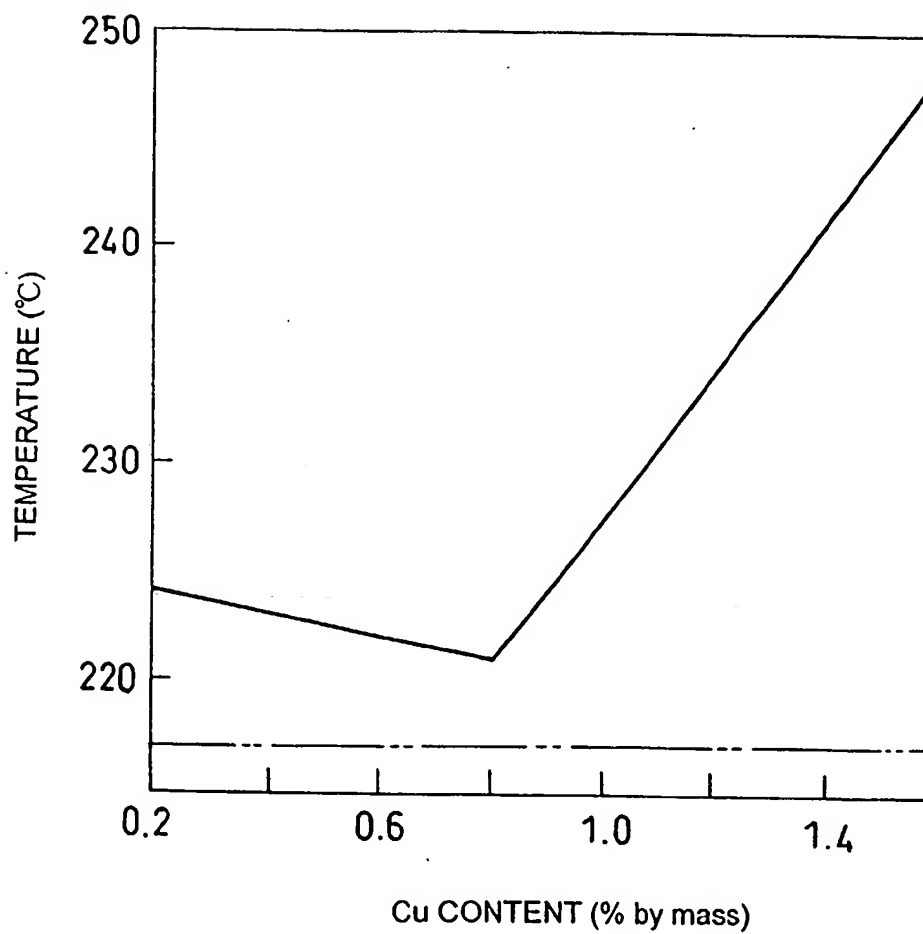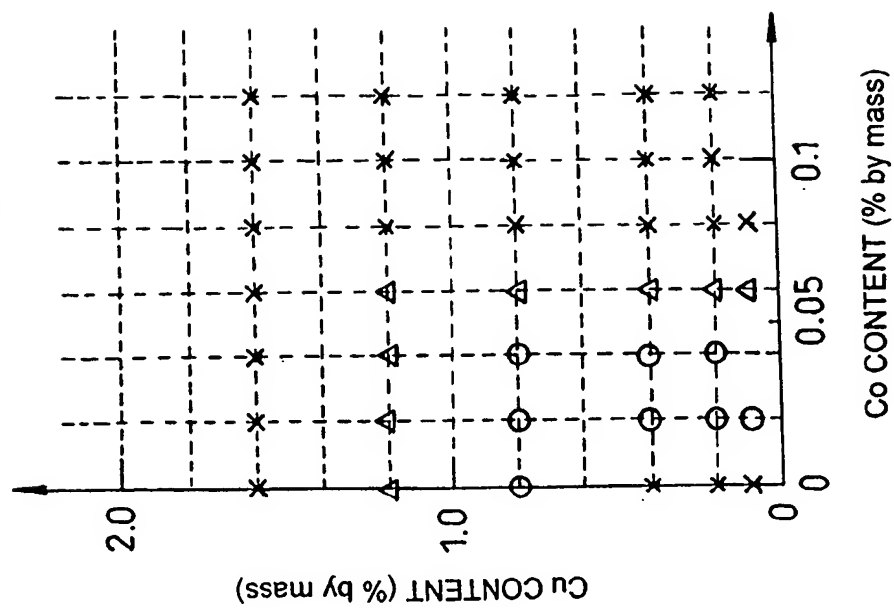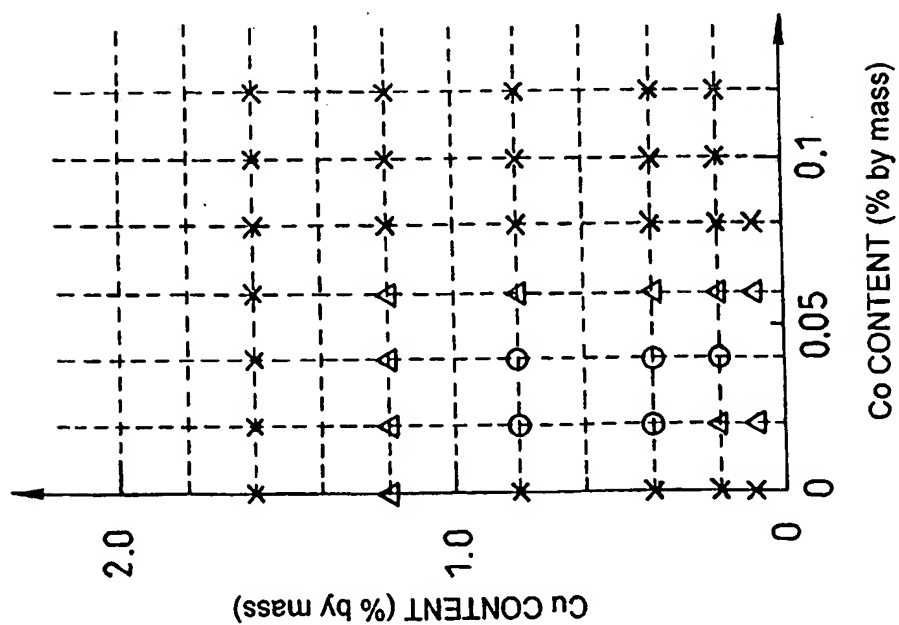11. A method for mounting an electronic part comprising the step of:

soldering an electronic part on a circuit formed on a surface of a printed wiring board with a solder consisting essentially of 1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, and the remaining of Sn and inevitable impurities.

12. A method for mounting an electronic part comprising the step of:

soldering an electronic part on a circuit formed on a surface of a printed wiring board with a solder consisting essentially of 1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, 0.02% to 0.06% of Ni by mass, and the remaining of Sn and inevitable impurities.

13. A method for mounting an electronic part comprising the step of:

soldering an electronic part on a circuit formed on a surface of a printed wiring board with a solder consisting essentially of 1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, 0.02% to 0.06% of Fe by mass, and the remaining of Sn and inevitable impurities.

14. A method for mounting an electronic part comprising the step of:

> soldering an electronic part on a circuit formed on a surface of a printed wiring board with a solder consisting essentially of 1.0% to 4.0% of Ag by mass, 0.2% to 1.3% of Cu by mass, 0.02% to 0.06% of Co by mass, 0.02% to 0.06% of Ni by mass, 0.02% to 0.06% of Fe by mass, and the remaining of Sn and inevitable impurities.

15. The method for mounting an electronic part according to any one of claims 11 to 14, **characterized in that** the liquidus temperature of said solder is 240°C or less, and that the melting rate of copper is 0.17 μm/sec or less.

FIG. 1

FIG. 2A

FIG. 2B

FIG. 3A

FIG. 3B

FIG. 4A

LIQUIDUS TEMPERATURE (℃)

Ni CONTENT (% by mass)

FIG. 4B

MELTING RATE OF COPPER (μm/sec.)

Ni CONTENT (% by mass)

FIG. 5

Co CONTENT (% by mass)
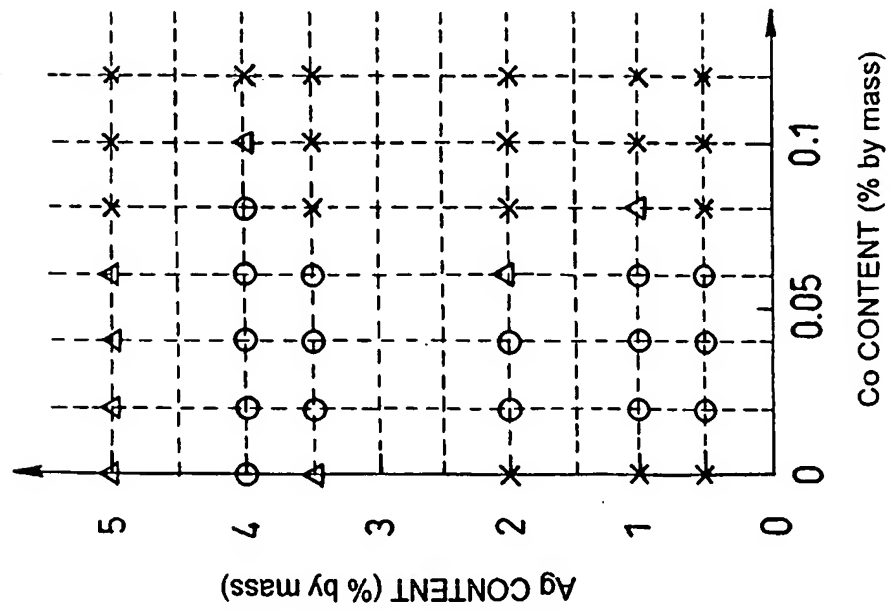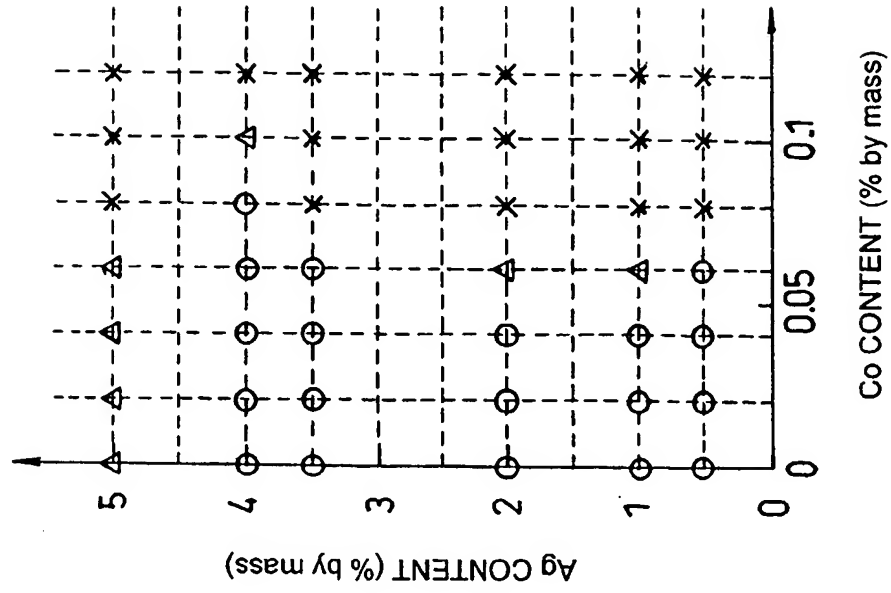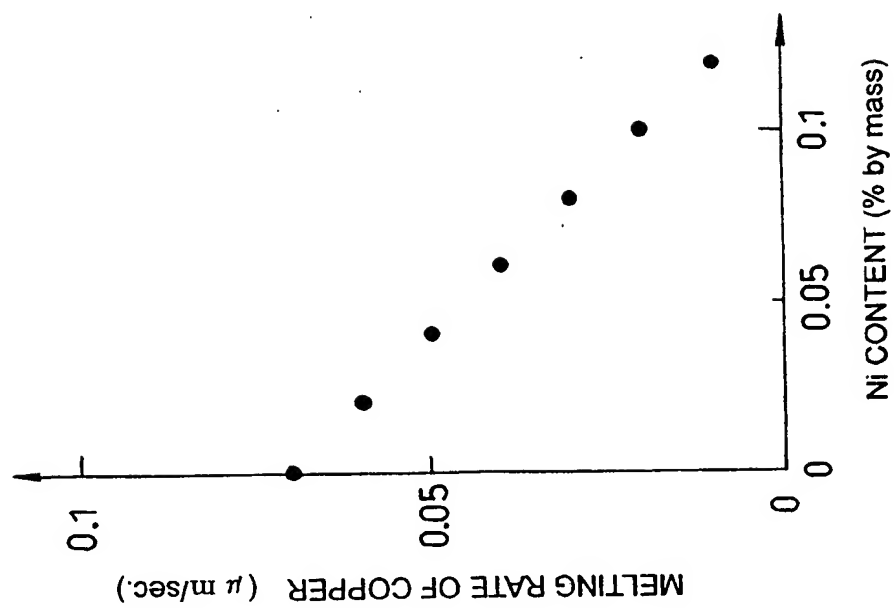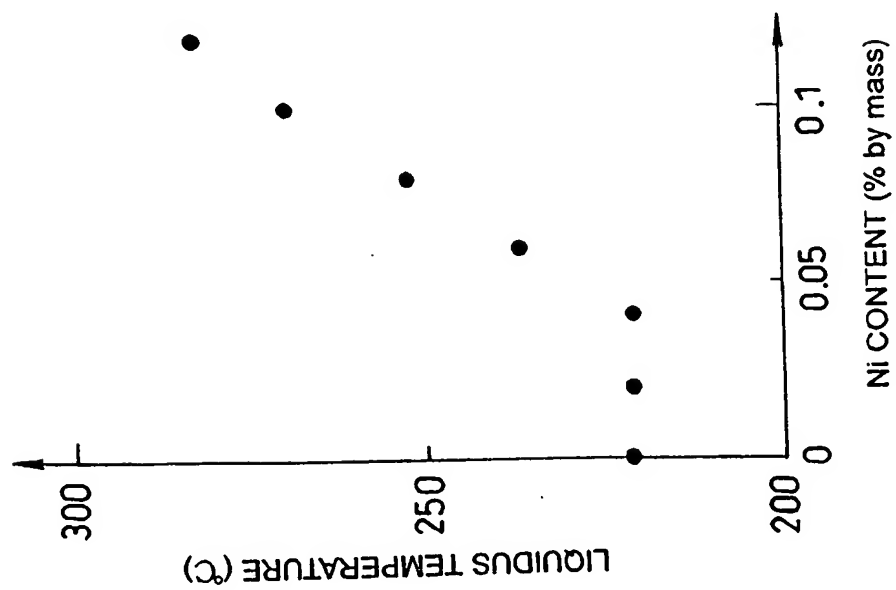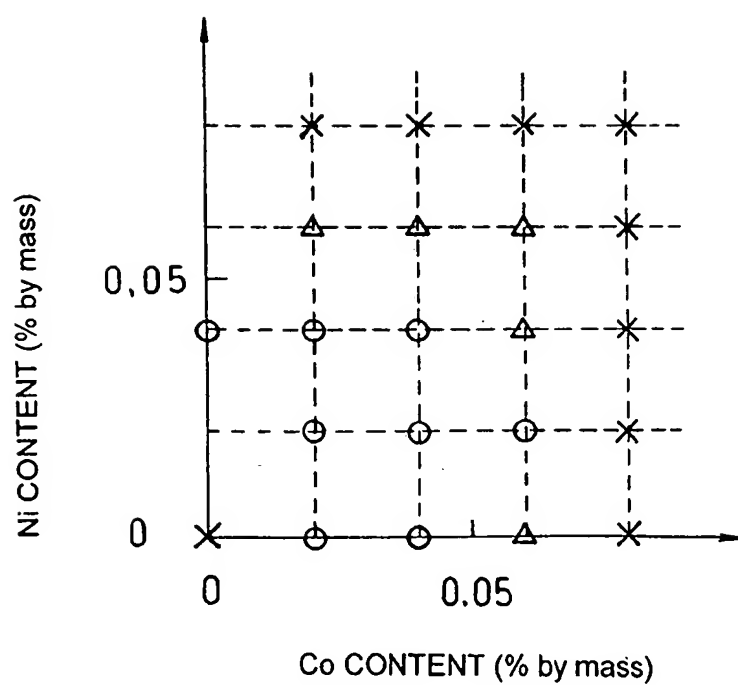
FIG. 6B
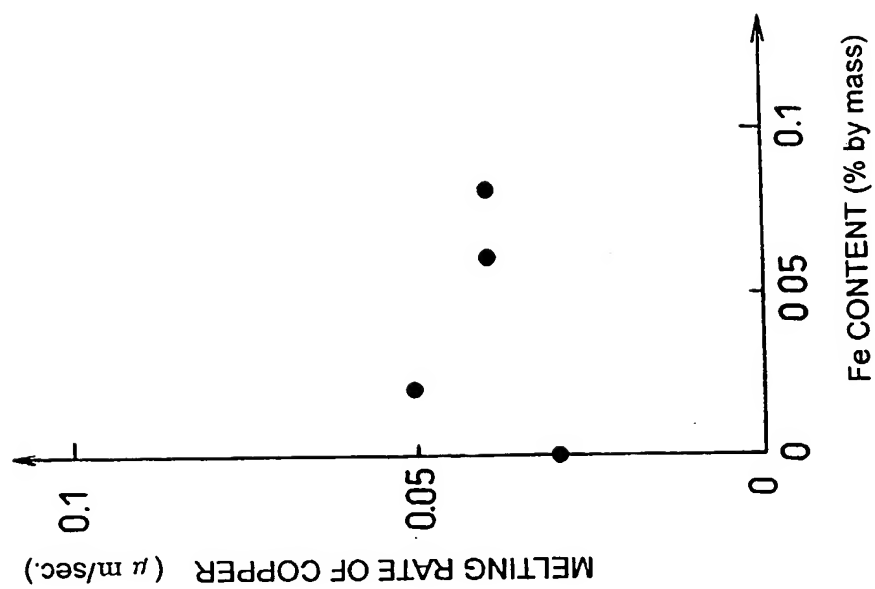
FIG. 6A
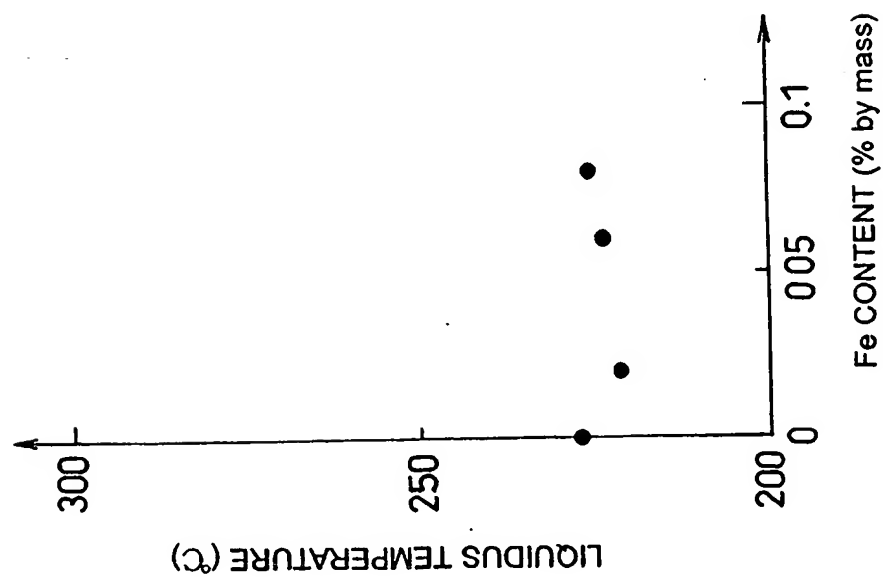
FIG. 7
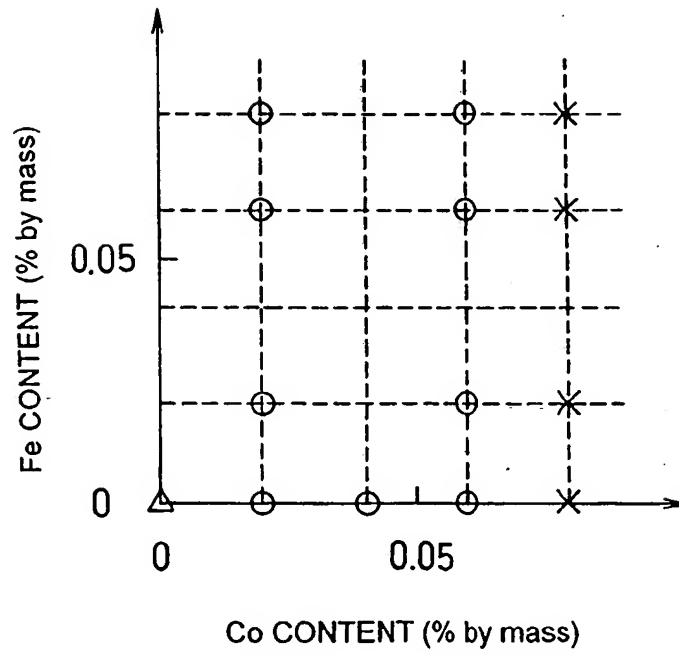
FIG. 8A
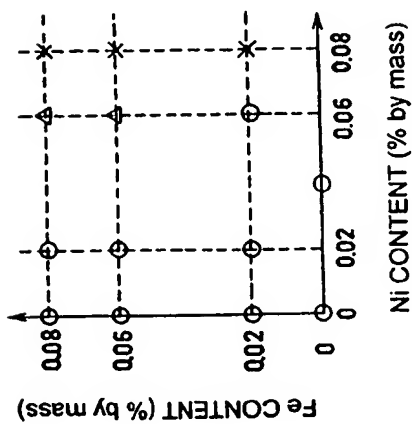
FIG. 8B
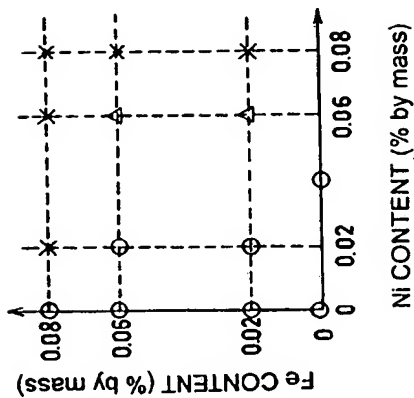
FIG. 8C
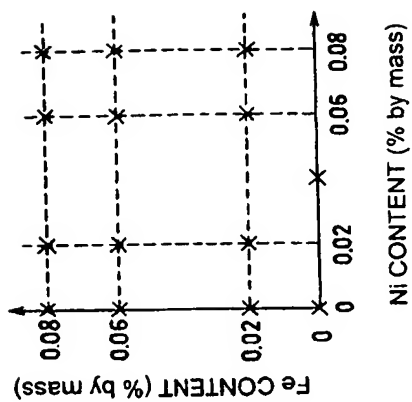
FIG. 9B
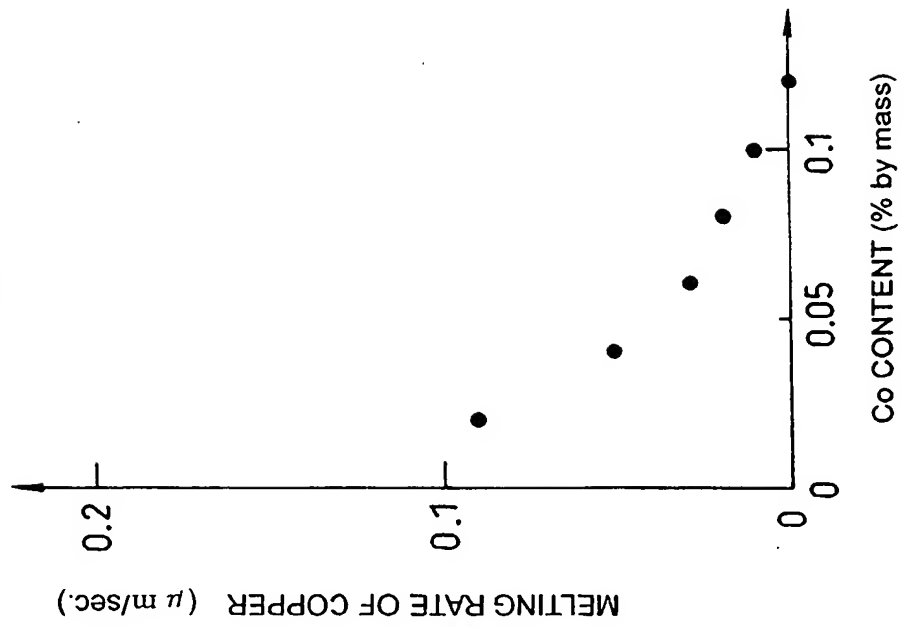
FIG. 9A
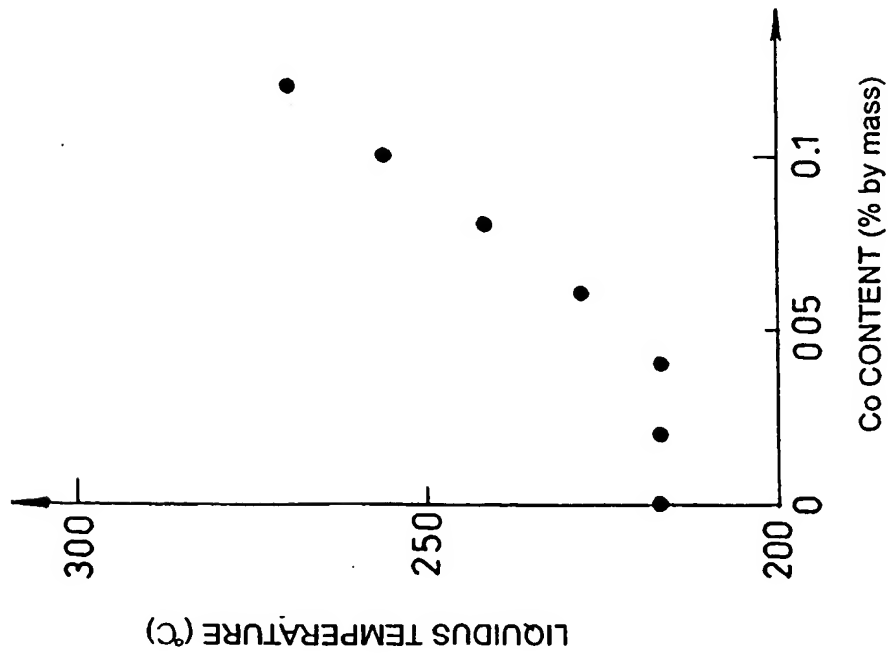
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 April 2002	Mollet. G

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